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NATIONAL BUREAU OF STANDARDS WASHINGTON DC  
LASER COOLING AND TRAPPING OF NEUTRAL ATOMS.(U)  
SEP 81 W D PHILLIPS

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(6) Summary Report on  
Laser Cooling and Trapping of Neutral Atoms,

LEVEL II

Carried out in the  
Electrical Measurements and Standards Division  
Center for Absolute Physical Quantities  
(National Bureau of Standards)  
Gaithersburg, MD

1 October 1980 - 30 September 1981

Principal Investigator: William D. Phillips

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Response to Summary Questionnaire  
(contract period ending 30 September 1981)

1. Principle Investigator: William D. Phillips
2. Contract Description: We are investigating experimental methods for laser cooling of neutral atoms, and possible applications of cooled atoms in trapping schemes, or slow beams, to high resolution spectroscopy and frequency standards.
3. The highest resolution spectroscopy is ultimately limited by processes which relate to atomic velocities such as second order Doppler shift and transit time effects. Laser cooling of ions in traps promises to deal with these problems, but there is a great deal of interest in achieving the same benefits for neutral species. Unfortunately, compared to ions, neutrals interact very weakly with external electromagnetic fields, so that it is much more difficult to trap them. Proposed traps using laser fields and electrostatic fields have not yet been realized, and successful trapping in magnetic fields has never been put to practical use. Much of the difficulty centers on the very small energy depth of the neutral traps, and the difficulty in cooling atoms contained in such a trap, in contrast to the situation with ion traps. As a result, much of the interest now centers on the cooling of free atoms, either as a preparation for loading into a trap or for use in an ultra-slow beam.
4. One key problem in atom cooling experiments has been the evaluation of the effects of the cooling laser. Because of the optical pumping which occurs along with cooling, it is often difficult to properly interpret the results. We have developed a method where the cooling laser is turned off abruptly and atoms which have been affected by that laser are then velocity analyzed, via their Doppler shifts, using a second laser. The actual cooling is accomplished by several different schemes. In the simplest, a near resonant laser is directed against the atomic beam, and a small velocity group of atoms are slightly slowed and bunched before being optically pumped. Adding a magnetic field along the beam and using circularly polarized light increases the interaction time by inhibiting optical pumping. In a more sophisticated scheme. The magnetic field varies along the direction of the beam so that a spatially changing Zeeman shift compensates for the changing Doppler shift as the atoms decelerate.
5. During the past contract period we have reconfirmed that data obtained by fast scanning a cooling laser and observing fluorescence induced by that laser is seriously complicated by the optical pumping process. We have developed the detection scheme described above to avoid this problem and have observed deceleration of atoms both with and without a magnetic field. With a magnetic field, we have reduced atomic velocities by about one third of the most probable velocity. Work is now underway to confirm these results using time-of-flight methods and to increase the amount of deceleration.
6. "Rapid Frequency Scanning of Ring Dye Lasers" by W. D. Phillips, to be published in Applied Optics, (1981).

"Laser Deceleration of Neutral Atoms", by W. D. Phillips and H. Metcalf, to be published, Bull. Am. Phys. Soc. (1981).

Other papers pertaining to this research are in preparation.

7. No extenuating circumstances.
8. No unspent funds are expected.
9. No graduate students are involved in this project.
10. The principle investigator is one of the scientists who receive partial support for the determination of the fine structure constant from the Department of Energy. Support under that grant is \$15,000 for the period 1 July 1981 - 30 June 1982.

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THIS REPORT

We have demonstrated the deceleration of an atomic sodium beam by means of photon pressure. Near resonant light from a counter-propagating (cooling) laser beam is absorbed by the atoms, causing them to slow down. The deceleration is observed by means of Doppler velocity analysis using a second (probe) laser. We modulate the cooling laser on and off while using time resolved observation of the fluorescence induced by the second laser; this allows observation of the effects of the cooling laser when the cooling laser light is not present. We have used circularly polarized light and a strong magnetic field in the direction of the cooling laser to avoid optical pumping of the atoms, a process which limits the amount of momentum which can be transferred to the atoms.